A NEW KAPITZA INVESTIGATION: DETECTING BACKSCATTERED
PHONONS WITH TUNNEL JUNCTION AND BOLOMETER SIMULTANEOUSLY

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At phonon frequencies above c.100 GHz the heat transfer across the interface between a solid and helium increases drastically over the values expected by the acoustical mismatch of the two materials. In the acoustical model it is assumed that phonons are transmitted directly i.e. without changing their frequencies. In this paper, however, we will show that the phonons undergo frequency conversion in the first two atomic layers of helium at the solid.

For experimental proof it is necessary to analyze how the frequency distribution of the incident phonons is affected by the helium. Therefore, we used monochromatic phonons generated and detected by superconducting tunnel junctions. For a qualitative frequency analysis we could use the detector junction in two states. In the "usual" junction state it was only sensitive to phonons with energies higher than the energy gap $2\Delta_0$ (c.120 GHz with Al:O). If the bias current was increased until one of the films became normal at a weak spot the detector behaved as a weak link and was now sensitive to the total energy regardless of frequency.

For the investigation described here we used phonon pulses of 290 GHz which were generated at one side of a Si crystal by a Sn junction. The phonons propagated along the 111 direction to the far side of the crystal where they were scattered. The backscattered phonons were detected on the generator side. The reflecting surface was either in vacuum or could be exposed to helium gas of various pressures.

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Fig. 1 shows the transverse echo measured by the junction (a) and the bolometer (b) together with the He pressures. The traces 1 (without He) were of different shape due to a slightly higher time constant of the bolometer. But this did not affect the results. When He was introduced, the echoes decreased strongly but differently depending on the detector state. The bolometer showed an additional time delay at low pressures where trace 2 and 3 even crossed trace 1. This delay was only weak with the junction detector. In order to compare the reflected intensities we integrated over the total echo areas. These areas were normalized to the ones without helium to account for the different sensitivities of the two detectors. The results are plotted in Fig. 2 as a function of the He pressure.

The bolometer shows that no energy is lost up to a pressure of $10^{-4}$ Torr i.e. the whole energy is reemitted into the solid. The junction, however, exhibited a remarkable decrease already at a pressure below $10^{-6}$ Torr or a film of 1.4 atomic layers. It follows that the backscattered phonons were no longer monochromatic but were down-converted to frequencies below $2\Delta_D/h$.

At pressures above $10^{-4}$ Torr, the bolometer intensity began also to decrease down to 35% of its original value. In this pressure regime, the junction showed an additional decrease and its intensity was always less than that of the bolometer. The decrease of the bolometer signal can be understood using simple gas kinetic arguments. Let us assume that a fraction $\eta_0$ of the in-